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AGRICULTURAL MEMORANDUM NO 954 - S N WASS, SEPTEMBER 1982
GLASSHOUSE HEATING EFFICIENCY - 1982 RESULTS

SUMMARY

A simple model to calculate glasshouse energy requirements has been developed and tested over the last 3 years (Wass 1980, 1981). This memorandum describes the results of comparisons made between the model's estimates and growers fuel records during 1982.

INTRODUCTION

Heat lost through the glasshouse skin due to the wind and temperature gradient is balanced against the solar contribution, CO_2 production and the heating system with an adjustment for the ground heat flux after sunrise and sunset. Hourly estimates of heat requirement are based on data from the nearest representative meteorological station, the glasshouse dimensions, temperature regimes and the appropriate transmission coefficient which depends upon the use of thermal screens. Hourly estimates are summed to give weekly totals which are then compared with the energy available from the fuel burnt.

RESULTS

By expressing the seasons estimates as a percentage of the growers total fuel use we have a conversion factor which is not only a measure of efficiency but may be used to scale individual weekly estimates. This method has been applied to readings sent in by five tomato producers and one AYR chrysanthemum grower in South West England and South Wales. From the results plotted in figure 2-7 it can be seen that by applying this technique the model tends to overestimate the fuel use in winter and underestimates in summer. This is partly because the model assumes internal day temperatures are achieved immediately at dawn whereas in practice, during cold weather, it may take 2 or 3 hours and is also due due to heating systems running less efficiently when not working near capacity. Combined conversion ratios for the 5 tomato growers based on similar ground areas are plotted against the energy needs for 22 weeks in figure 1 and shows a statistically significant correlation of efficiency with heat requirement.

To enable comparisons between growers to be made more easily results have been standardised to the requirement for 1 ha of ground area for weeks 1 through 21 and are shown in table 1. Results are arranged in order of energy demand, for a block with glass to floor ratio (F) of 1.23 kept at stage 3 blueprint temperatures of 20°C by day and 16°C by night (column 2). Column 3 shows the calculated requirement based on actual dimensions and temperature regimes and most importantly the next column shows the energy used by the growers. Conversion ratios, as described earlier, have been calculated and where possible compared with last years' findings.

TABLE 1 ENERGY REQUIREMENTS WEEKS 1-21

NURSERY	F RATIO	ENERGY REQUIRED PER HECTARE (MWh)			CONVERSION FACTOR*	
		STANDARD	CALCULATED	FROM FUEL	1982	1981
A	1.18	2205	1940	2424	79.8	
B	1.37	2245	1873	2950	63.6	
C	1.25	2300	2160	2680	81.0	78.1
D	1.28	2343	1977	3109	64.7	62.9
E	1.40	2442	2607	3077	84.6	81.0
F_1	1.22	2480	916	1607	57.0	
F_2			1440		89.6	

* using all available data
F_1 - with blackout screens on 81% of nursery) See assessment
F_2 - without blackout screens)

It is obviously important to size the boiler according to energy demand and a study of table 2 below reveals results consistent with figure 1. Taking week 7 as a period in which there was a high demand but when all heating systems should have been able to cope, the boiler rating has been expressed as a fraction of the energy demand for that week.

TABLE 2

GROWER	A	B	C	D	E	F
DEMAND WK 7 (MWh ha^{-1})	164	160	169	160	226	149*
BOILER RATING (MWh ha^{-1})	390	598	374	393	531	606
RATING/DEMAND	2.38	3.74	2.21	2.46	2.35	4.07

* average of demand calculated with and without screens.

Nurseries B & F have a poor overall efficiency and a high boiler to requirement ratio whereas the more efficient heating systems have a low boiler to requirement ratio. Moreover the 3 growers with the best conversion factors use 2 or 3 boilers in tandem and are thus more able to match energy supply and demand.

Referring back to table 1 it can be seen that reported fuel use (column 4) is not directly comparable with standard blueprint requirements (column 2). Some of these anamolies are discussed in the following section. However for a complete economic assessment of the different temperature regimes and planting dates, account must be taken of yield and harvest date.

GROWER A **Figure 2**

A well sheltered site contributes to the lowest blueprint requirement but a low glass to floor ratio and growing at lower night temperatures helped achieve the lowest actual fuel consumption per hectare. Temperatures were held 2°C - 3°C above target most mornings which lowers the conversion ratio since the model is not programmed to allow for this.

GROWER B **Figure 3**

Aiming for lower than standard daytime temperatures in general and allowing them to fall to 13°C during the exceptionally cold weather in January led to the lowest calculated fuel demand of all 5 tomato growers. Unfortunately a poor utilisation of fuel is responsible for one of the highest actual consumptions per ha. Weekly conversion ratios fall from above 80% at the start of the year to below 40% in mid June. Whilst some of this decrease in performance can be attributed to lowering heating system efficiency as the load is reduced, as demonstrated in figure 1, the performance is well below that of most of the other growers. Enquiries revealed that the thermostats, which normally operate the vents, were overidden by a humidity sensor after April 6. It is probably this practice which kept the conversion ratio below 55% on 8 out of the 10 remaining weeks. Assuming average heating system efficiencies from figure 1 at this fairly low level of demand would produce a saving of about 7800 litres per ha without venting. Mean conversion factors have been superimposed in figure 3.

GROWER C **Figure 4**

This is a well maintained modern enterprise and at 81% is the second most efficient producer which together with reduced temperatures helped him achieve the second lowest fuel costs. The meteorological readings used in the calculations were made only 3 km away which leads to a good fit of the observed and estimated fuel use. A new block with double glazed sidewalls which now accounts for 37% of the nursery's glass and a larger boiler came into service this season. It was hoped for a bigger improvement over last year than that achieved but unfortunately the flue damper stopped working for a few weeks from early March which is reflected in the conversion factors remaining below 80% thereafter. The older but smaller boiler may have been more efficient late season but its use was not possible because of installation work being carried out. However next season holds some scope for further improvement.

GROWER D **Figure 5**

Until the end of March this grower aimed for blueprint temperatures and then dropped them by 2°C during the day. Thermal screens over 51% of his tomato acreage kept the calculated requirement down to 1977 MWh ha but a low conversion ratio (64.7%) resulted in the highest fuel use of the 5 tomato producers. As can be seen from figure 5, boiler output was insufficient to meet demand in some weeks at the calculated efficiency and it was reported that it sometimes took 4 hours to achieve day temperatures in severe weather. Between weeks 8 and 14 more fuel was burnt than predicted by the model which suggests that the overall conversion factor is around 60%.

GROWER E **Figure 6**

Grower E has taken some steps to compensate for the exposed nature of his nursery but nevertheless has the highest blueprint requirement of the tomato growers. A large glass to floor ratio of 1.40 combined with near blueprint temperatures being maintained throughout the period gives the highest calculated requirement of 2607 MWh ha . It is only be allowing temperatures to drop by a few degrees for a time during the nights and by being efficient in the production and distribution of this energy that the actual use has been kept down to 3077 MWh ha .

GROWER F Figure 7

The performance of this grower is the most difficult to assess because he produces AYR chrysanthemums with blackout screens over 81% of the crop. Although the model assumes a lower transmission coefficient which is independent of windspeed it has not been fully tested with thermal screens. Referring back to table 1 it can be seen that if he were producing tomatoes at blueprint temperatures in our standard house then he has the highest energy requirement of all because of his exposed position. If we assume that no benefit is to be gained from the blackouts then the conversion ratio is 89.6%. However if we assume that the blackouts restrict thermal transmission to the value used in the model then the conversion factor drops to 57.0%. The true value is probably somewhere between the two.

Table 2 shows this nursery to have the largest boiler rating to requirement ratio and should have been able to meet the demand in week 7 but reported fuel use fell short of that expected. Since no accurate temperature checks are kept it is possible that internal temperatures were allowed to drop below target. If both boilers are in use then they are ill matched to the heating demand and figure 1 suggests that a conversion factor more than 63% cannot be expected.

CONCLUSIONS

The model was developed to calculate the variations of fuel use because of differing climates and growing temperatures but this memorandum suggests that is is robust enought to make an assessment of heating system efficiency. Although the results of the 3 growers who recorded both years indicate an improvement; with the more severe weather in 1982 temperatures took longer to achieve and boiler efficiencies were higher. Calculated conversion factors, based on weeks of more modest energy demands, were within 1% of the previous years' for all 3 growers.

By scrutinising weekly estimates and fuel readings it has been possible to identify areas where improvements may be sought. Such areas include the cost of venting at B, the effect of the flue damper at C, a consistent low efficiency at D, the cost of growing at high temperatures at E, the exposed nature of the site at F and the general decrease in heating system performance with lowering demand relative to rated output. Investigations into this last point may lead to different recommendations and a possible increase in heating efficiency.

S N WASS
Bristol
September 1982

REFERENCES

1. WASS, S N (1980) - The Solar Contribution to Glasshouse Heating. Agricultural Memorandum No 903

2. WASS, S N (1981) - Estimating Glasshouse Heating Efficiency. Agricultural Memorandum No 924

FIGURE 1

VARIATION OF CONVERSION RATIO WITH WEEKLY CALCULATED ENERGY REQUIREMENT

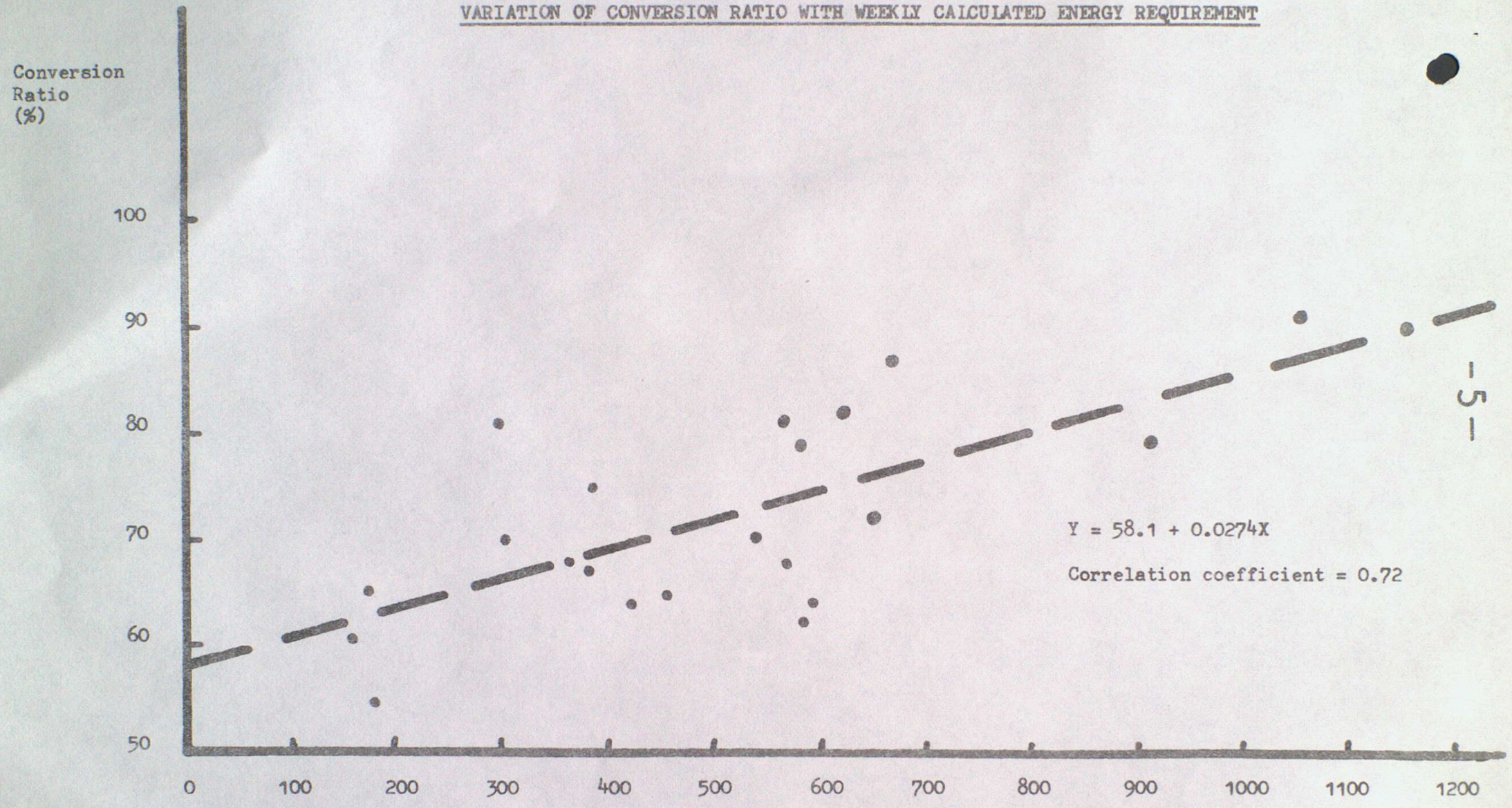
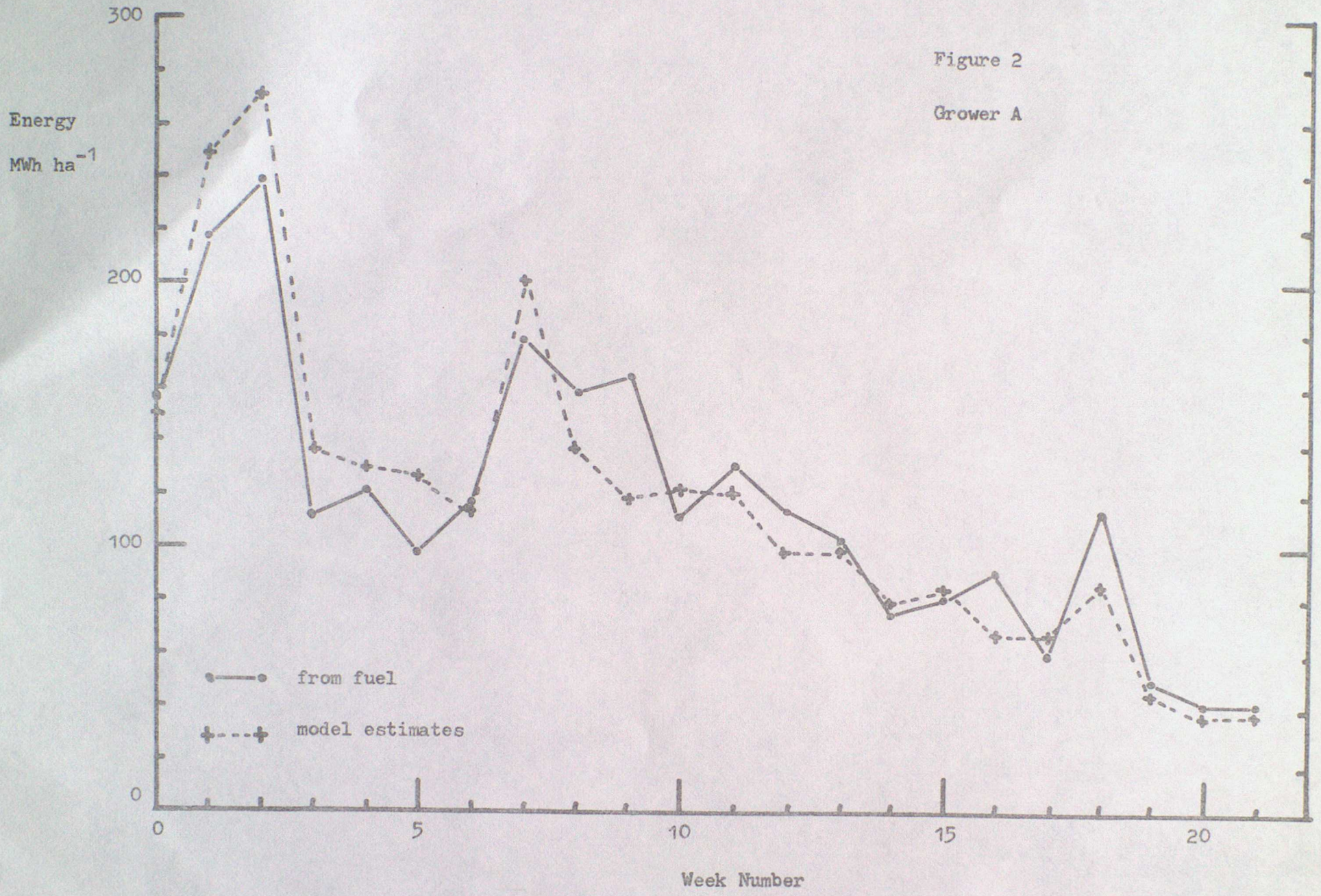


Figure 2

Grower A



1982 RESULTS

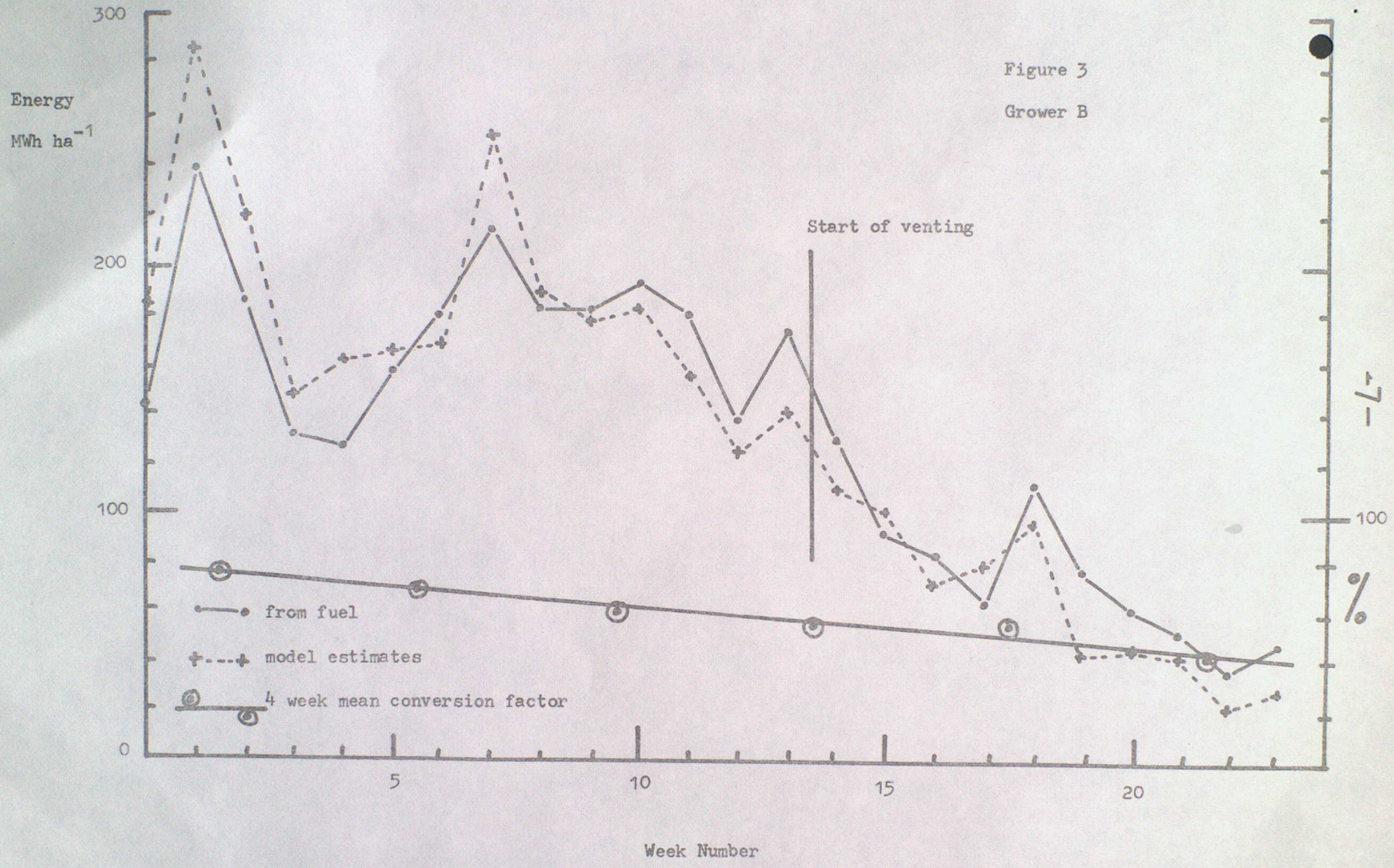


Figure 3

Grower B

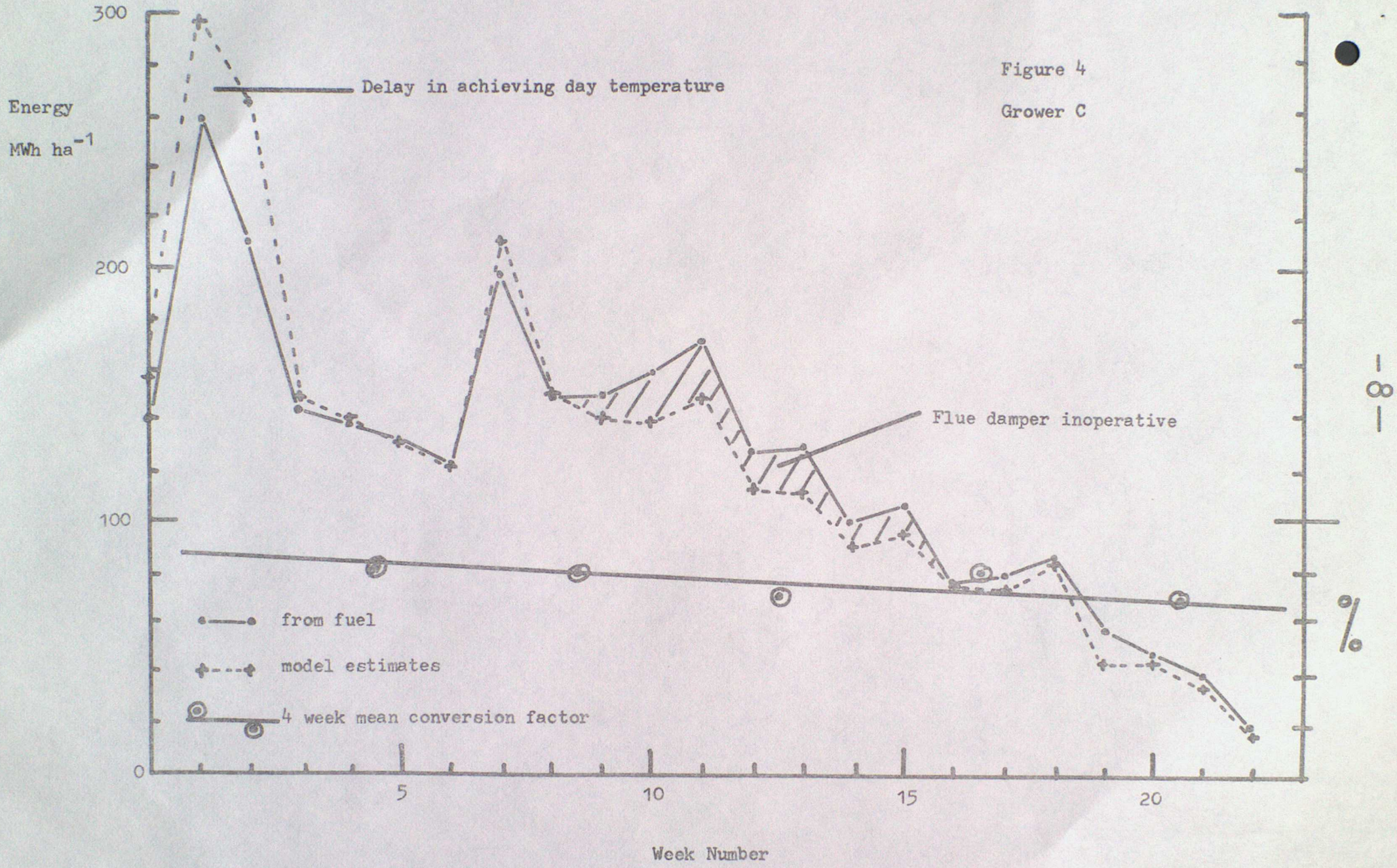


Figure 4

Grower C

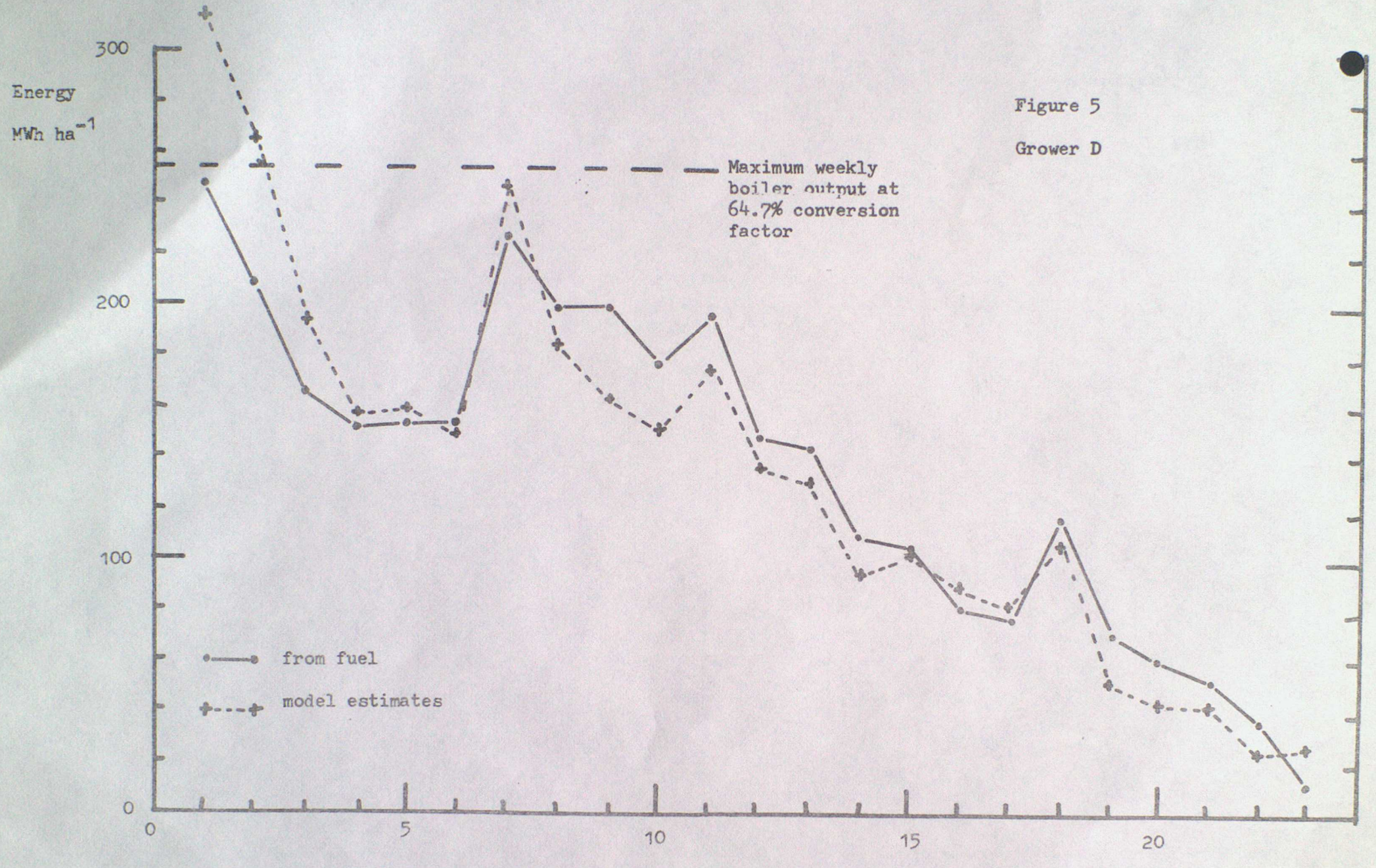


Figure 5

Grower D

1982 RESULTS

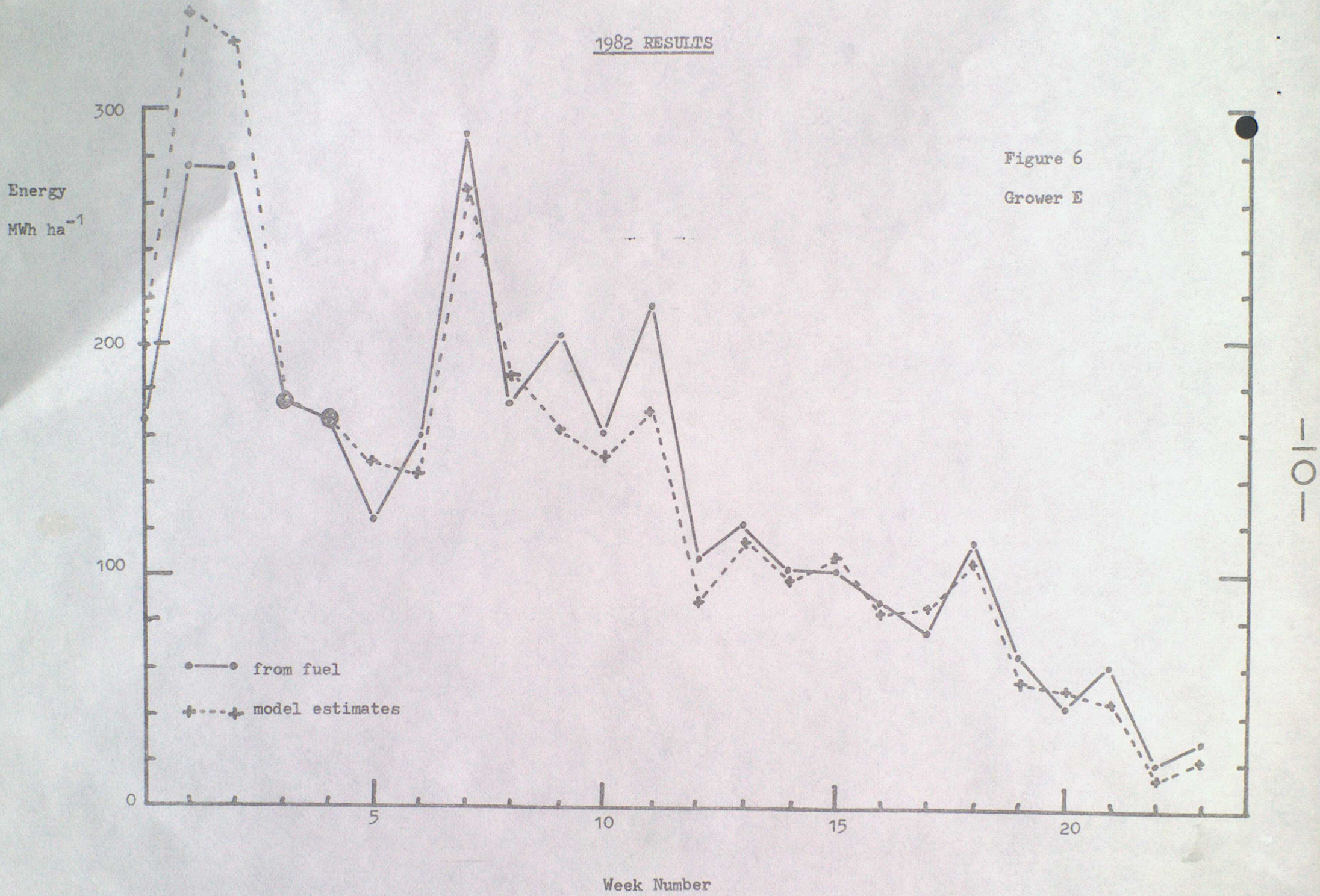


Figure 6

Grower E

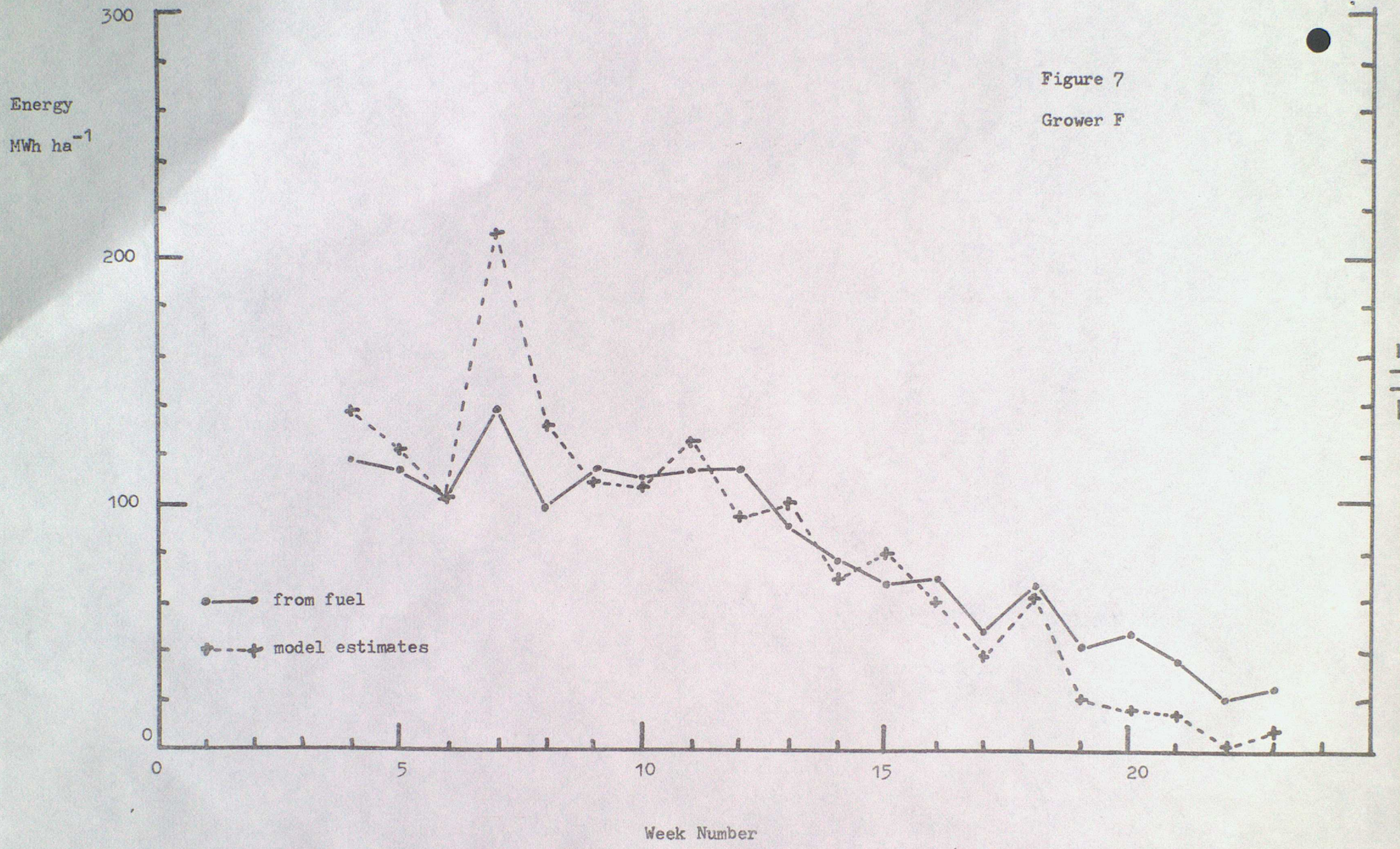


Figure 7

Grower F